4P

Final Technical Report
to
National Aeronautics and Space Administration

on
Grant No. NAG-1-1116

for the period
March 1, 1990 to December 30, 1991

Principal Investigator

H.T. Banks
Center for Applied Mathematical Sciences
University of Southern California
Los Angeles, CA 90089-1113

April 1992

Analytical Model Development for Damping in Flexible Structures: Estimation and Control

Summary

Substantial progress has been made on developing analytical models for grid and truss structures. In references [1], [2], inverse problems for stiffness and damping in plates and grids are addressed. The question of stable approximations (needed in feedback control problems) for hyperbolic systems is explored in [3]. The results obtained in such studies were used in control calculations for structures with piezoceramic actuators discussed in [6], [8]. The difficulties when one chooses the inappropriate approximation scheme in either an estimation problem or a feedback control problem are illustrated in [5].

Homogenization techniques for grids and trusses have been a major focus of our efforts. In [4] we use these homogenization ideas with experimental data from 2-D grid experiments to demonstrate the accuracy of the models in predicting frequencies. A full theoretical treatment of the model development is given in [9].

The homogenization ideas of [4] and [9] and the piezoceramic actuator models of [6], [8] are intimately related in the following way. Future smart material structures will be constructed from composite materials with micro units (piezo sensory/actuator elements) imbedded in a regular (checkerboard) pattern that will be appropriately modeled by homogenization methods. Our efforts are turning to these ideas now and the experiences

from the efforts of [4], [6], [8], [9] will be extremely valuable in the development of this emerging technology.

List of References Supported in Part by NASA-NAG-1-1116

1. H.T. Banks and D.A. Rebnord, Analytic semigroups; applications to inverse problems for flexible structures, CAMS Tech. Rep. 90–3, January 1990, University of Southern California; in *Differential Equations with Applications*, (*Intl. Conf. Proc.*, Retzhof, Austria), Marcel Dekkar, 1991, pp. 21–35.

2. H.T. Banks and D.A. Rebnord, Estimation of material parameters for grid structures, CAMS Tech. Rep. 90–4, March 1990, University of Southern California; *J. Math. Systems, Estimation and Control*, **1** (1991), 107–130.

3. H.T. Banks, K. Ito and C. Wang, Exponentially stable approximations of weakly damped wave equations, CAMS Tech. Rep. 91–12, May 1991, University of Southern California, in *DPS Control and Applications*, Birkhäuser, *Intl. Ser. Num. Math.*, Vol. 100, 1991, pp. 1–33.

4. H.T. Banks, D. Cioranescu, A. Das, R. Miller, and D.A. Rebnord, Homogenization techniques and estimation of material parameters in distributed structures, CAMS

Tech. Rep. 91–16, May 1991, University of Southern California; in *Computation and Control II*, (K. Bowers and J. Lund, eds.), Birkhäuser, 1991, pp. 13–30.

5. H.T. Banks, Computational issues in parameter estimation and feedback problems for partial differential equation systems, CAMS Tech. Rep. 91–17, June 1991, University of Southern California; *Physica D*, to appear.

6. H.T. Banks, W. Fang and R.C. Smith, Active noise control; piezoceramic actuators in fluid/structure interaction models, CAMS Tech. Rep. 91–21, August 1991, University of Southern California; *Proc. 29th IEEE Conf. Dec. and Control*, Brighton, England, December 1991, pp. 2328–2333.

7. H.T. Banks, Y. Wang, and D.J. Inman, Bending and shear damping in beams; frequency domain estimation techniques, CAMS Tech. Rep. 91–25, September 1991, University of Southern California; *ASME J. Vibration and Acoustics*, submitted.

8. H.T. Banks, W. Fang, R.J. Silcox, R. Smith, Approximation methods for control of acoustic/structure models with piezoceramic actuators, CAMS Tech. Rep. 91–26, December 1991, University of Southern California; *J. Intell. Material Systems and Structures*, submitted.

9. H.T. Banks, D. Cioranescu, and D.A. Rebnord, Homogenization models for 2-D grid structures, preprint, April 1992; to be submitted.